With the Author's compliments.

JOHNSON

ON THE

BEAR CREEK HYDROGRAPHIC SURVEY, BRITISH COLUMBIA.

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BY

FRANCIS ROBERT JOHNSON, M. Inst. C.E.

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Sect. II.—OTHER SELECTED PAPERS.

(*Paper No. 3957.*)

"The Bear Creek Hydrographic Survey, British Columbia."

By Francis Robert Johnson, M. Inst. C.E.

This survey in a mountainous district of British Columbia includes a large area covered by stadia levelling, where the difference of elevation in a single sight often exceeded that found in 4 or 5 miles in the Author's previous experience on an Indian survey, in 1893.[1] In that survey levelling by angles of inclination played an important part.

The Okanagan Valley, within which the present survey was carried out, has come into prominence during the last few years as a fruit-growing district, but owing to the rainfall being slight (10 to 15 inches) and variable in distribution, irrigation is to a certain extent necessary.

Under these circumstances the Provincial Government decided to have surveys made of the various rivers and creeks, and as the instructions issued were of a general nature—details being left more or less to the discretion of the surveyor—the Author decided to carry out his share of the work entirely by tacheometry. He also came to the conclusion that, in view of the great value of levels for irrigation purposes, and the fact that at considerable altitudes barometer levels are somewhat untrustworthy, it would be well worth while to take a little extra trouble, and carry a line of stadia levels throughout the survey. This was done with satisfactory results, and it is hoped that a general description of the survey may be of service to the younger members of the profession, particularly those who may be contemplating a future career in one or other of the great dominions beyond the seas.

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[1] "The Survey of the Manmad-Dhulia Railway, India." Minutes of Proceedings Inst. C.E., vol. cxv, p. 343.

Preliminary Considerations.

Okanagan Lake, on the west shore of which this survey commenced, is over 70 miles in length from north to south, and from 1 to 3 miles in breadth. It is generally of considerable depth.

There are numerous towns and villages in its vicinity, the chief of which is Vernon, and a considerable number of creeks discharge their water into it from the surrounding mountains.

The first camp was pitched by the 1st June, 1910, and the field-work ended on the 1st December, a period of 6 months. A couple of weeks were lost in drying and storing the equipment and settling accounts, after which the Author returned to headquarters at Vernon to compute and plot the work, an operation occupying about 7 weeks.

The cost of the first season's operations was naturally greater than usual, but the Author believes that with two or three suitable assistants to carry out the routine part of the work, and a draftsman to plot everything from the commencement, the cost would be considerably reduced.

The first point to be decided was the best unit of measurement to adopt. In British Columbia all land surveys are carried out with the Gunters chain, with the exception of those within town and city limits, where the 100-foot chain is generally used. For the stadia levels a foot unit would have been preferable, but as the instructions called for the survey into lots of any land suitable for agriculture or grazing, which might be found while traversing the creeks, the Author decided to use the link throughout, because it would have been very inconvenient to change the unit in the course of the work. The resulting computations were very laborious, however, and it would be much better in surveys of this nature to avoid including the complication of the demarcation of crown lands, and use the foot as the unit.

Traverses and Survey Marks.

The conclusion was reached that where wagon roads or trails existed it would be best to run a traverse along them to tie in with the creek traverse, so that there might be a check on the work without serious expense. While on the creek traverse the lines had to be cut out of the timber and bush almost continuously; naturally on the road traverse there was no cutting, and on the trails only a little.

The result was that double, and sometimes triple traverses, with reversed cross connections, were run all the way from the mouth of Bear Creek to a little east of the confluence of the north and south forks (close to bench-marks 27 and 41). The remaining traverses are unchecked for the present, except as regards azimuth, when the necessary symbol on the map indicates that an observation was secured. This is partly shown on *Fig. 1*, which is a reduced reproduction of part of the original map on which the survey was plotted.

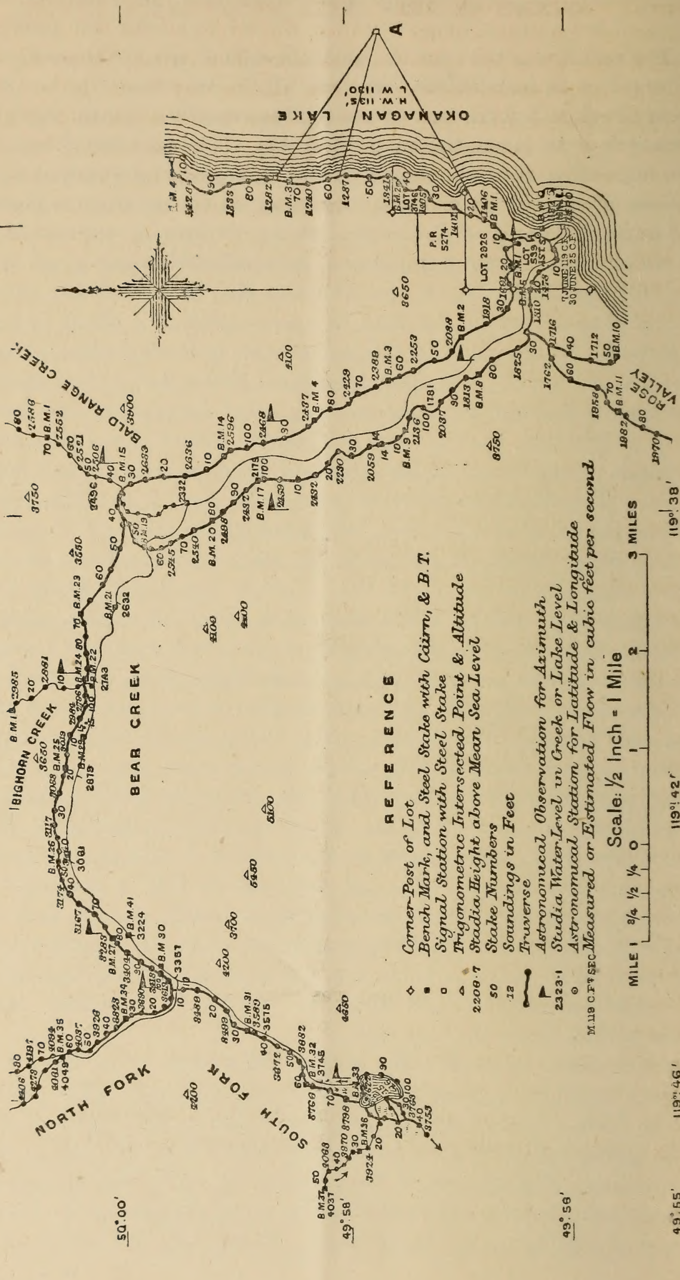
The total length of the main double traverse is approximately 24 miles, and two main junctions were effected, namely, at stake No. 14, near B.M. No. 9, and at stake No. 15, near B.M. No. 29. The closing errors in the first case were latitude 1 chain 16 links, departure 83 links; and in the second case, latitude 28 links, departure 1 chain 5 links. It should be noted that a large proportion of the first difference was necessarily carried forward to the second point of junction, thus proving the general theory that stadia errors decrease proportionally with length of traverse, i.e., are not cumulative. The duplicate traverse from B.M. No. 19 to B.M. No. 41 follows the creek more or less, but is not shown in *Fig 1.*

As a check on the Okanagan Lake shore traverse, bases of from 2 to 4 chains were set off at the principal headlands, where there were steel flag stations. The mean of a round of angles, taken to these bases, gave very close results as compared with the traverse, the distance from headland to headland varying from $\frac{1}{4}$ to $\frac{3}{4}$ mile.

To avoid confusion with the demarcation of land lots, a steel stake was used instead of a wooden post; owing to the numerous bush fires also, it is believed this will be found more permanent. The stakes were driven with the head a little below the surface, and then covered with a cairn of rocks, whenever that was possible. These permanent marks were placed roughly about 1 mile apart, that is, close to every bench-mark, and were referred to a bearing tree. Other stations were fixed on prominent headlands, on both the east and west shores of Okanagan Lake, to mark trigonometrical points to sight on, so as to connect the work on both sides, and act as a check on azimuth and distance. In *Fig. 1* is shown one of these points, A, on the east side.

Bench-marks were in every case on the stumps of as large trees as were available (generally felled for the purpose). The practice was to drive a heavy 6-inch iron spike in the centre, and nail on to them galvanized iron plates, having the letters B.M. and the number painted on. The azimuth of the bench-mark spike was read to the nearest minute from the steel stake in every case, so as to provide means of picking up the work again. In all sixty-six bench-marks

Fig. 1.



PLAN OF PART OF SURVEY.

were established, each with a steel stake and cairn station and a bearing tree within a short distance, the triple marks being made to form a triangle when that was feasible. The bearing trees are also marked with galvanized iron plates, painted with the letters B.T. and the distance in links; they face towards the mark referred to.

Levels and Stadia Work.

The barometer heights were recorded for each bench-mark, but in most cases it was not possible to return often enough to obtain a good average. The ordinary $2\frac{1}{2}$-inch instrument was carried as a rule on account of its portability, but occasionally a 5-inch instrument was used. In one instance where the latter was used to check the stadia height of one of the bench-marks, and the day was suitable, with steady atmospheric conditions, a mean of an up and down reading gave 2,980 feet above sea-level as compared with 2,982·7 feet obtained by the stadia. This was the best result recorded, probably more by good luck than anything else, as much greater differences were often observed. As regards the stadia levels, the maximum closing error as checked over the 24 miles of traverse previously alluded to came out + or − 4 feet, which was well within the accuracy necessary on creeks falling sometimes hundreds of feet in a mile.

The practice was to read the vertical angle, to the nearest minute, to "height of instrument" on the staff, this being measured at every station. The Author generally employed an ordinary sliding 14-feet Sopwith staff for the stadia, repainted with the link unit. All the staves used by him have a fitting at the side to take a small telescope, and enable the staff-holder to sight the instrument with the staff at right angles to the line of sight when required.

As a rule a hand-level was used, and the staff was kept vertical for all sights up to 15°, but above that inclination, in addition to the vertical sight, a duplicate was taken to the staff, held at right angles. The first was generally used for the reduction of the levels and both first and second for comparison as regards the distance, preference being always given to the latter. This was found to be absolutely necessary on steep mountain sides, angles up to 35° and 40° being common, sometimes for considerable distances. The greatest altitude reached on the traverses was 4,870 feet.

Astronomical Observations.

The astronomical work was the foundation of the survey, as without it, it would have been impossible to maintain a correct azimuth.

The circuitous nature of the creek and the rough and mountainous forest country made it impossible to run continuous straight lines of any length—in fact every station was on a different alignment. There were on an average about twenty-five to thirty stations per mile, some of them from sheer necessity less than a chain apart, which was greatly against accurate work.

It was also necessary to take advantage of every possible opening in the timber and bush to avoid heavy clearing on the lines, much of the fir at the higher altitude being 3 to 4 feet in diameter ; and trees had often to be felled to take the sun. Every precaution was taken by reversals and repetitions to obtain accurate results, and the necessary checks. The sun was generally observed for azimuth, the stars for latitude and time, and the moon for longitude. Until near the completion of the season's work, however, the principal observations were confined to, first, latitude sufficiently exact for azimuth purposes ; secondly, time for the same purpose, and to rate the watch ; and, thirdly, the azimuth observations themselves to check the angular work of the survey.

The last were taken often enough to confine any error within narrow limits, and thus enable it to be corrected without much trouble or expense.

In one instance a slip of ½ degree was thus discovered and localized, and in others small cumulative errors which were adjusted, so that practically the closing errors previously referred to are due to measurement and not to bearings. With regard to the latitude observations (generally meridian altitude of stars between June and October), the results obtained were not so good as those secured by the Author in India, and it is believed that unequal refraction was the cause of this, partly owing to great variations of temperature between day and night, and partly to the presence of much smoke from numerous bush fires, and dust in the air. Towards the close of the season's work, when the camp returned to the zero station on Okanagan Lake, the air was in much better condition, and good results were obtained.

An occultation of τ Aquarii by the moon, and also a moon culmination, were observed for longitude with the necessary series of time observations. The exact apparent position of the occulted star at

the date was obtained from the Director of the U.S. Nautical Almanac Office, Washington Naval Observatory, but the correction for the place of the moon as tabulated in the ephemeris could not be ascertained, as the meridian observations made at the Observatory are not reduced until several months afterwards.

It is probable, however, that as the moon's places are now better known, this correction is not of so much consequence as it would have been years ago. The results obtained for the longitude were, from the occultation, 7 H. 58 M. 20 Sec., and from the culmination, 7 H. 58 M. 13 Sec.—the mean 7 H. 58 M. 16½ Sec., that is 119° 34′ 07·5″ west of Greenwich, being adopted as the position of the astronomical station. Circummeridian altitudes of various north and south stars, and altitudes of Polaris, both in and out of the meridian, gave 49° 56′ 15″ N. for the latitude.

A stop-watch recording to fifths of a second was used for all the observations, and the occultation was observed with a portable 1¾-inch Ross astronomical telescope, having rack and pinion for focussing, and a Huyghenian ocular, power 50, mounted on a small table-stand with altazimuth motions.

The 5-inch Troughton-Simms tacheometer was used for the final astronomical observations, but nearly all the traverses and azimuths, except at the starting point of the survey, were carried out with a Watts 4-inch transit, having a relatively large object-glass, and powers 18 to 30.

The instruments, of course, were very carefully adjusted and tested from time to time.

General Details of Survey.

For many miles from its mouth, Bear Creek itself is in a deep rock canyon, sometimes with quite inaccessible sides, and it is only on the upper reaches that it comes out but little below the general surface of the country. Where inaccessible for instrument work, the practice was to traverse at varying distances from the top of the canyon as circumstances required, always returning close enough to try and obtain a sight right into the creek bed, at intervals of from 5 to 15 chains, according to the topography.

In these mountains numerous very severe fluctuations of the compass were observed, sometimes as much as 10° difference from the usual variation (24½ east), which shows what very erroneous alignment of section or lot lines may result in cases where an astronomical observation cannot be secured.

Continuous gauging of the stream at any one site was impossible

with the available staff, but the two gaugings shown near the lake in. *Fig. 1* represent actual measured flows. As the low-water flow, however, is practically monopolized already in most cases for irrigation, and at the best does not amount to much, the whole problem hinges upon storage, and what there is to store from the spring floods.

Considering the great fall per mile on most of these streams, very favourable storage sites cannot be expected to be plentiful, and the greatest hope lies in being able to utilize the natural lakes that often exist near the watershed, where some flattening off is generally found. The lake on the south fork, shown in *Fig. 1*, is an example, and possibly from 1,000 to 2,000 acre-feet could be stored by lowering the outlet 10 feet, and raising the existing water level a like amount by embankments. At present practically no records of precipitation and run-off are available, which would be of any value to engineers.

The scale used in plotting the work was 4 inches to the mile. The rectangular projection based on the mid-latitude was first of all prepared, and afterwards the co-ordinate lines were laid down with a steel tape and beam compasses. Conventional symbols were used, as shown in *Fig. 1*, attached to the original plan, and on the plan were also given Tables showing the stadia and barometer heights in feet of each permanent steel bench-mark, and the co-ordinates of each station with distance and azimuth to the bearing tree.

The Tables also included a list of the corner-posts of previous Crown Land surveys as found on the ground, with the elevation at the corner, and the co-ordinates from zero, as computed by the Author, together with the marks on the posts. Stadia levels were available for every stake on the traverses, but these were only recorded on the original plan for every fifth station.

All heights were originally referred to a gauge fixed by the Author to a pier near the reference point of the survey. The top of this gauge was eventually accepted as practically the high-water mark of Okanagan Lake, recorded on the Dominion railway belt map of 1909 as 1,135 feet above mean sea-level. The heights were then all reduced to feet above mean sea-level, for insertion on the plan.

Crown Land Surveys in British Columbia.

The Government system of surveys is based on townships of 6 miles square, subdivided into thirty-six sections, each of 640 acres. These sections are generally subdivided into quarter sections of 160 acres.

As a rule the original surveys of this Province are made in more or less thick timber and bush, and the boundary lines have to be cut out, to enable the posts to be located at all the corners.

Where suitable land is not found in large enough blocks, the available area is surveyed into lots, generally of 160 or 320 acres, but often fractional, each of which has a number assigned to it, as the result of a special survey. A few of these lots are shown in *Fig. 1*.

Generally speaking, the cardinal directions are followed, but in some cases, a lake, river, or other natural feature is made one of the boundaries.

All traverses for crown lands have to be closed, so that there may be proof of the area, and the field notes with plan and declaration are sworn to, and submitted in duplicate to the Surveyor-General.

The Paper is accompanied by five tracings, from which the Figure in the text has been prepared.

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